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EXPORT SUPPLY AND IMPORT DEMAND ELASTICITIES IN THE JAPANESE TEXTILE INDUSTRY: A PRODUCTION THEORY APPROACH

by
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EXPORT SUPPLY AND IMPORT DEMAND ELASTICITIES IN THE JAPANESE TEXTILE INDUSTRY: A PRODUCTION THEORY APPROACH

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ABSTRACT

Agricultural goods are often treated as final goods in applied agricultural trade models. However, many agricultural traded goods are intermediate in nature. In this paper a production theory approach is applied in deriving export supply and import demand functions for the Japanese textile industry. The production theory approach derives import demand and export supply functions from the assumption of profit maximizing (cost minimizing) behavior. The behavioral implications of the profit maximization framework are used to specify producer supply and demand functions which are consistent with economic theory. Flexible functional forms are estimated in the econometric model and the concavity restrictions implied by economic theory are checked and imposed.

Elasticities derived from the production theory approach are also compared with results based on a single equation specification of the aggregate import demand equation. A major shortcoming of the single equation approach is the lack of theoretical guidance for choosing the appropriate specification.

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The Japanese textile industry offers an important case study for modelling export supply and import demand elasticities. The production theory approach is used to provide insight into adjustments in the Japanese textile industry in response to declining international competitiveness and the impact of industrial policy. By incorporating important information about the nature of the commodity, this approach provides a theoretically sound framework for deriving estimates of elasticities.

A primary objective of this paper is to apply the production theory approach for deriving export supply and import demand functions developed by Kohli (1983) and Diewert and Morrison (1988) to the Japanese textile industry. Imports such as cotton and textile products are intermediate goods in the production process and do not directly enter the consumer sector. The production theory approach is especially appropriate for analyzing trade in intermediate goods which represent a major share of international trade.

The production theory approach derives import demand and export supply functions from the assumption of profit maximizing (cost minimizing) behavior. The behavioral implications of the profit maximization framework are used to specify producer supply and demand functions which are consistent with economic theory. Flexible functional forms are estimated in the econometric model and the concavity restriction implied by economic theory are checked and imposed.

Derived demand functions for cotton imports and labor employed in the Japanese textile sector are obtained from a restricted profit function and estimated subject to the restrictions implied by economic theory. Domestic and export supply equations for textiles are also derived and estimated. The relevant elasticities are calculated and analyzed.

Elasticities derived from the production theory approach are also compared with results based on a single equation specification of the aggregate import demand equation. Selection of the appropriate model and functional form to estimate single equation import demand equations was examined extensively by Thursby and Thursby (1984). In the single equation approach, the selection of the appropriate model for estimation of import demand elasticity is guided almost entirely by the statistical properties of the specification.

A major shortcoming of this approach is the lack of theoretical guidance for choosing the appropriate specification. Specification of the import demand equation becomes an empirical issue based primarily on econometric tests. Compared with the production theory approach, the single equation approach is not as data intensive and may be more readily applied to alternative commodities, particularly at the disaggregated level.

The paper consists of four sections, beginning with a brief description of the Japanese textile industry to motivate the choice of problem area. In the second section, the theoretical model is outlined and specified using a flexible functional form based on the biquadratic restricted profit function. The third section summarizes the data sources and estimation results for the restricted profit function along with the single equation import demand specification. Section four summarizes the conclusions and implications.

I. Industrial Policy and the Japanese Textile Industry

The Japanese textile industry is a prime example of an industry whose competitive status has been dramatically altered due to shifts in comparative advantage since 1950. The textile and apparel industries were a major contributor to Japanese postwar industrial development and foreign trade. In 1950, the textile and apparel sector accounted for 48.2 percent of total exports and 23.7 percent of total shipments of manufacturing industries.

The international competitiveness of the Japanese textile industry lead to trade restrictions in Europe and the U.S. directed against the textile industry. Import pressure from Japanese textile producers on U.S. markets in the 1960's produced the first set of voluntary quota restraints negotiated with the Japanese.

By the 1970's the competitive position of the Japanese textile industry had been eroded due to domestic wage increases and exchange rate appreciation. The textile and apparel sector produced only 4.8 percent of total export earnings and 5.2 percent of total shipments by manufacturing industries in 1980. Imports of textile goods into Japan increased dramatically and by 1970 the trade balance of textile goods was negative.

Japanese industrial policy for dealing with declining sectors of the Japanese economy is prominently illustrated in the cotton textile industry. Japanese industrial policy, designed to facilitate adjustment to declining demand in specific industries, was formulated in the comprehensive 1978 law entitled "Temporary Measures for Stabilization of Specific Depressed Industries." That year the Japanese cotton textile industry along with fourteen other industries was designated as "structurally depressed" allowing the Ministry of International Trade and Industry (MITI) to begin formulating plans for industry-wide capacity reductions. The Japanese textile industry was one of three industries from this group which was not energy-intensive and thus was not severely impacted by the 1973 and 1979 oil shocks.

Cline (1987) noted that adjustments in the Japanese textile industry were consistent with the "Japanese tradition of government-business cooperation and conscious formulation of industrial policy." This process of adjustment and down-sizing that occurred in the Japanese textile industry differed from the protectionist policies such as import quotas adopted by other industrial countries.

The basic features of the adjustment process, which are extensively described in Ghadar et al. (1987), were tailored to match the industrial structure of the textile industry and relied on the international trading expertise of the Japanese textile firms. Because Japanese textile and apparel firms are extremely small, they were able to specialize in textile materials and product lines and to adjust quickly to shifts in export markets. Taxes and financial incentives were used to encourage vertical cooperation between small firms and larger fiber makers and spinners. Vertically integrated Japanese firms succeeded in transferring fabric operations to newly industrialized countries while continuing to supply these fabric operations with domestically produced textile fibers.

From the perspective of cotton producers in the United States, Japan continues to be a major market for exports of cotton. Japan is the largest importer of cotton, buying over 800,000 metric tons during 1986-87. In 1986-87, the United States accounted for the largest share of Japanese cotton imports at 40 percent. Other important sources of cotton include the People's Republic of China (16 percent), Pakistan (13 percent), and Australia (9 percent). While U.S. exports of cotton to Japan have remained relatively stable over time, trade flows and shares for other countries have changed significantly. The People's Republic of China is currently the second largest exporter of cotton to Japan.

Most cotton imported by Japan is used in the production of textiles. Japan was second only to the United States in total value of textiles and apparels produced in 1980, with output worth over $51 billion. Japanese exports of textiles totaled almost $6 billion in 1980.

II. Theoretical Model for Export and Import Demand Functions

Firms in the textile sector, facing perfect competition in output and factor markets, are assumed to maximize profits by choosing domestic inputs, including imports and the amount to supply. Equilibrium in the textile sector results from the maximization of gross textile production subject to the technology, the endowments of domestic factors, and import and output prices. Following Kohli (1983) and Diewert and Morrison (1988), we assume that the restricted profit function for the textile sector is defined by:

$$\pi^t(p^t,w^t,K^t) \equiv \max\ [p^t\cdot x + w^t\cdot y : (x, y, K) \in S^t] \qquad (1)$$

Let S^t be the production possibility set for the Japanese textile sector in period t. Net domestic output for the textile sector is denoted by the N-dimensional vector $x = (x_1,\ldots,x_N)$, where positive elements represent production and negative elements represent inputs. Internationally traded goods are denoted by the M-dimensional vector $y = (y_1,\ldots,y_M)$, where positive elements represent exports and negative elements are imported goods used by the textile sector. Let p be the vector of domestic prices facing domestic producers and w be the vector of international prices. The capital stock used by the textile sector in time period t is defined by K^t.

Assuming that π is differentiable at the point p^* and w^*, Hotelling's lemma can be used to derive the profit-maximizing net output vector and the net export vector for the textile sector. In notation,

$$x^t = \nabla_p \pi^t(p^t, w^t, K^t) \qquad (2)$$

$$y^t = \nabla_w \pi^t(p^t, w^t, K^t) \qquad \text{for } t=1,\ldots,T \qquad (3)$$

where ∇_p is the vector differential operator. The notation $\nabla_p \pi^t(p^t, w^t, K^t)$ represents the vector of first derivatives of π with respect to the elements of the output price vector p. Differentiating the restricted profit function with respect to each of the components of p^t yields (a) the domestic supply function of textiles, and (b) (minus) the labor demand function of the textile sector. The export supply function for textiles from Japan is obtained by differentiating the restricted profit function with respect to w_1. Differentiating with respect to w_2 yields (minus) the cotton import demand function.

Applied to the Japanese textile industry, the model is based on two domestic goods: x_1 is the quantity of textiles produced for domestic consumption, and x_2 is (minus) the labor employed for the textile sector. The two goods traded internationally are denoted by y_1, the textiles exported, and y_2 which is (minus) the quantity of cotton imported to Japan.

Empirical Implementation and Estimation of the Model

To characterize the technology of the textile sector along with the substitution possibilities, the functional form for the restricted profit function is specified as a normalized biquadratic form defined by Diewert (1986). The biquadratic restricted profit function, an adaptation of the generalized McFadden cost function, is a flexible functional form for a constant returns to scale technology.

Following Diewert and Morrison (1988), the profit function, $\pi^t(p^t, w^t, K^t)$, in time period t is defined as

$$\pi^t(p^t, w^t, K^t)/K^t = [p^t, w^t]\mathbf{a} + [p^t, w^t]\mathbf{b}\tau + \tfrac{1}{2}\, [p^t_2, \ldots, p^t_N;\ w^t]\mathbf{B}[p^t_2, \ldots, p^t_N;\ w^t]/p_1 \qquad (4)$$

where $K^t > 0$ represents the quantity of capital used in time period t, τ^t is an indicator of technical progress in time period t, p^t represents a N×1 vector of domestic prices, and w^t represents a M×1 vector of international prices. The unknown parameters of the biquadratic restricted profit function denoted in bold are the (N + M) dimensional vectors **a** and **b** along with the (N - 1 + M) × (N - 1 + M) symmetric matrix **B**. The individual parameters of the **B** matrix are denoted by β_{ij}.

The choice of the normalized biquadratic profit function was based on a number of factors. The biquadratic belongs to the class of functional forms with global curvature properties. Functions which possess global curvature properties meet the convexity conditions required of a well-behaved profit function for any valid price vector. Applied general equilibrium models require functional forms for production and utility function which meet the curvature restrictions, justifying the choice of the biquadratic profit function.

Morey (1986) discussed methods for checking, testing and imposing curvature properties on both the true function and the estimated function. When the estimated function and the true function take on the same functional form, both functions must possess the desired curvature properties globally. The generalized quadratic profit function along with the quadratic, the Generalized McFadden, and the Generalized Barnett meet these restrictions. Most other flexible functional forms, including the translog, do not satisfy this requirement.

For the case of two outputs and two inputs, the resulting system of estimated equations for the restricted biquadratic is given by

$$x_1/K = a_1 + b_1\tau^t - \tfrac{1}{2}\beta_{11}(p_2/p_1)^2 - \tfrac{1}{2}\beta_{22}(w_1/p_1)^2 - \tfrac{1}{2}\beta_{33}(w_2/p_1)^2$$
$$- \beta_{12}p_2w_1/(p^2{}_1) - \beta_{13}p_2w_2/(p^2{}_1) - \beta_{23}w_1w_2/(p^2{}_1) + u_1^t \qquad (5)$$

$$x_2/K = a_2 + b_2\tau^t + \beta_{11}(p_2/p_1) + \beta_{12}(w_1/p_1) + \beta_{13}(w_2/p_1) + u_2^t \qquad (6)$$

$$y_1/K = a_3 + b_3\tau^t + \beta_{12}(p_2/p_1) + \beta_{22}(w_1/p_1) + \beta_{23}(w_2/p_1) + u_3^t \qquad (7)$$

$$y_2/K = a_4 + b_4\tau^t + \beta_{13}(p_2/p_1) + \beta_{23}(w_1/p_1) + \beta_{33}(w_2/p_1) + u_4^t \qquad (8)$$

The additive error vectors u_i^t appended to equations (5)--(8) are assumed to be independently distributed and to follow a multivariate normal distribution with means equal to zero and covariance matrix Ω. Maximum likelihood estimates for the parameters a_i, b_i, and B are obtained using Zellner's seemingly unrelated regression model.

Economic theory requires that any well-behaved profit function should be convex in prices. However, the curvature conditions for the biquadratic restricted profit function were violated when estimating the unconstrained linear model. The convexity conditions for the biquadratic restricted profit function are satisfied globally if the B matrix is positive semi-definite, that is, if the eigenvalues of the Hessian are all non-negative. One of the eigenvalues is negative for the unconstrained model implying that the profit function is not consistent with economic theory.

The convexity conditions are subsequently imposed on the system of demand and supply equations by reparameterizing the B matrix using the technique outlined by Morey. The components of the B matrix are replaced by the corresponding elements of the matrix TDT' where T is a 3×3 unit lower triangular matrix and D is a 3×3 diagonal matrix consisting of the Cholesky values of B. The system of demand and supply equations is then estimated using a nonlinear estimation technique.

The null hypothesis that the true profit function is globally convex in prices requires that the estimated B matrix be positive semi-definite. Reparameterizing B using the Cholesky decomposition, B is re-defined as:

$$B = [\ b_{ij}\ ] = TDT'.$$

The diagonal elements of the D matrix, or the Cholesky values, are denoted by $\hat{d}_{ii}$ and determine the sign definiteness of B. When all the $\hat{d}_{ii}$ are positive, the null hypothesis that the true restricted profit function is globally concave in prices cannot be rejected. Simultaneous tests that none of the $\hat{d}_{ii}$ are significantly less than zero are performed using Bonferroni t-statistics. The null hypothesis that each $\hat{d}_{ii} \geq 0$ is rejected at the α level of significance or above if

$$\hat{d}_{ii} < t^{*}_{\alpha}(\upsilon)\ [\mathrm{Var}(\hat{d}_{ii})]^{½} \text{ for at least one } i,$$

where

$$\alpha \leq \sum_{i=1}^{N} \dot{\alpha}$$

and υ represents the degrees of freedom. The critical t value for a nominal 0.05 level Bonferroni test of the null hypothesis is

$$t_{\delta/2}(25) = 2.28, \text{ where } \delta = 0.05/3 = 0.0167.$$

For the estimated $\hat{d}_{ii}$ the null hypothesis that each $\hat{d}_{ii} \geq 0$ is not rejected at the 0.05 level of significance. Global convexity is subsequently imposed on the estimated profit function. Any $\hat{d}_{ii}$ which is negative is replaced and estimated with $(d^{*}_{ii})^2$.

III. Data and Empirical Results

The primary data for the textile industry were obtained from Uno (1987) supplemented with private communications with the author. Annual data for the 1955-1980 period were used in the study. The two outputs considered in the analysis are textiles produced for domestic consumption and textiles exported. The two input are labor and cotton. Quantity and price data for domestic textile production, exports of textiles and labor employed in the textile industry were obtained from Uno.

Import price and quantity data for cotton were obtained from World Cotton Statistics published by the International Cotton Advisory Committee. Since no cotton is produced domestically, only imported cotton data were used. The price variable for cotton was constructed as trade weighted export price from the different import sources. Capital stock used in the Japanese textile industry was also obtained from Uno. Exchange rate data, required to express the profit function in domestic currency (Japanese yen), were obtained from the International Financial Statistics published by the International Monetary Fund.

The Estimated Elasticities

The estimated coefficients (Table 1) are used to calculate the supply and factor demand elasticities. In Table 2 through Table 5, the relevant elasticities for domestic and export supply and cotton and labor demand are summarized. The domestic supply and input demand elasticities are calculated with respect to the own price as well as cross prices. The calculated net domestic output elasticities with respect to domestic prices are:

$$\epsilon_{x_i p_j} = (\partial x_i/\partial p_j)(p_j/x_i) \quad i=1,2 \text{ and } j=1,2$$

The domestic output and input elasticities with respect to international prices are given by:

$$\epsilon_{x_i w_j} = (\partial x_i/\partial w_j)(w_j/x_i) \quad i=1,2 \text{ and } j=1,2$$

The export and import supply and demand elasticities are given by $\epsilon_{y_m p_j}$ and $\epsilon_{y_m w_j}$ for m = 1,2 and j = 1,2.

The elasticities are estimated at the mean for the complete sample period along with values for the years 1960, 1970, and 1980. Table 2 presents the domestic output supply elasticities with respect to the different prices. The results indicate that the domestic output supply elasticity with respect to its own price is inelastic at the mean with a value of 0.133. The domestic output supply elasticities with respect to input prices are negative, implying that an increase in input prices results in lower domestic supply.

TABLE 1. PARAMETER ESTIMATES FOR UNCONSTRAINED AND CONSTRAINED MODELS

Coefficients	Unconstrained Estimate	Standard Error	T ratio	Constrained Estimate
α_1	1502.10	82.980	18.102	1507.30
α_2	341.95	75.630	4.521	335.02
α_3	-189.34	23.229	-7.221	-196.10
α_4	-85.53	13.019	-6.723	-87.58
β_1	17.28	4.954	3.488	17.41
β_2	-2.64	1.285	-2.053	-2.74
β_3	3.94	0.507	7.771	4.09
β_4	1.81	0.288	6.291	1.83
β_{11}	2.69	61.408	0.044	0.52
β_{22}	31.17	15.486	2.013	27.09
β_{33}	4.25	4.451	0.956	3.76
β_{12}	-1.35	18.968	-0.071	4.00
β_{13}	11.95	11.573	1.032	6.05
β_{23}	6.64	3.572	1.860	72.11

TABLE 2. DOMESTIC SUPPLY ELASTICITIES

	ELASTICITY WITH RESPECT TO PRICE OF:			
YEAE	Domestic Textiles	Labor	Cotton Imports	Textile Exports
MEAN	0.133	-0.108	-0.123	-0.012
1960	0.054	-0.029	-0.051	-0.007
1970	0.099	-0.080	-0.090	-0.010
1980	0.373	-0.344	-0.345	-0.024

Table 3 summarizes the relevant elasticities for the supply of exports. The own price elasticity is 0.002 at the mean, indicating an inelastic supply of exports. The elasticity with respect to the domestic price is negative at -0.069 indicating that as domestic prices fall, more quantity is diverted to the export market. The elasticities with respect to input prices are positive and small.

The input demand elasticities for cotton are summarized in Table 4. The elasticity of the demand for cotton with respect to its own price, which is equivalent to the Japanese import demand elasticity for cotton, is inelastic at -0.352. Comparisons with previous studies should be made with care since explanatory variables may differ considerably between studies. Estimates of export demand elasticities for U.S. cotton summarized by Gardiner and Dixit (1987) found higher values in the range of -0.02 to -5.5. These values reflect the impact of substitutability among different sources.

The results also indicate some substitution between labor and cotton. The magnitude of this elasticity at -1.7 is surprising, since one would expect little substitution between labor and cotton. The elasticity with respect to domestic output price is positive and elastic with a value of 2.17. This indicates that as domestic textile prices increase more cotton will be imported. The elasticity with respect to the textile export price is negative and small at -0.091, indicating that as the price of exported textiles increases, there will be a small decline in the quantity of cotton

TABLE 3. EXPORT SUPPLY ELASTICITIES

	ELASTICITY WITH RESPECT TO PRICE OF:			
YEAE	Domestic Textiles	Labor	Cotton Imports	Textile Exports
MEAN	-0.069	0.039	0.028	0.002
1960	-0.035	0.011	0.024	0.020
1970	-0.059	0.035	0.023	0.010
1980	-0.123	0.089	0.033	0.010

TABLE 4. IMPORT DEMAND ELASTICITIES FOR COTTON

YEAR	ELASTICITY WITH RESPECT TO PRICE OF: Domestic Textiles	Labor	Cotton Imports	Textile Exports
MEAN	2.170	-1.726	-0.352	-0.091
1960	-0.525	-0.287	-0.181	-0.056
1970	2.113	-1.699	-0.319	-0.094
1980	6.330	-5.688	-0.586	-0.115

demanded.

The labor demand elasticities are listed in Table 5. The demand elasticity for labor with respect to the wage rate is inelastic. The elasticity with respect to export prices is negative and small at -0.11. The elasticity with respect to domestic price is elastic and positive. This result indicates that as the price of domestic textiles increases, there will be a large increase in the demand for labor. Again, the cross price elasticity with respect to the price of cotton is elastic and negative, indicating the potential for substitution between labor and cotton. The magnitude of the elasticity, however, is counter-intuitive as one would expect smaller substitution possibility between labor and cotton.

Comparison with the Single Equation Results

The results of the Japanese import demand elasticity for cotton in this study were compared with a single import demand equation of the Japanese demand for cotton. Thursby and Thursby (1984) suggested that statistical properties should give guide to the selection of appropriate models for the estimation of import demand elasticities. Consistency with the theoretical restrictions implied by economic theory is not a major criterion for choosing an appropriate specification in this modelling approach.

A single equation model was estimated in double-log form, specifying the quantity of imports in period t (Q_t) as a function of the log of the imported price of cotton (P_t) and real Gross Domestic Product (Y_t). The results, with the t-values in

TABLE 5. INPUT DEMAND ELASTICITIES FOR LABOR

YEAR	ELASTICITY WITH RESPECT TO PRICE OF: Domestic Textiles	Labor	Cotton Imports	Textile Exports
MEAN	5.043	-0.110	-4.593	-0.339
1960	2.941	-0.020	-2.684	-0.234
1970	4.768	-0.111	-4.295	0.360
1980	9.546	-0.407	-8.656	0.482

parentheses are summarized below:

$$Q_t = \underset{(15.02)}{6.005} - \underset{(-2.77)}{0.245}\ P_t + \underset{(5.16)}{0.194}\ Y_t \qquad (9)$$

The estimated import price elasticity of cotton is -0.245. This elasticity is 30 percent lower than the -0.352 estimate obtained using the production theory approach.

IV. Conclusions

In this paper the production theory approach for modelling trade in intermediate goods was applied to the Japanese textile industry. Domestic supply and export supply equations for domestic textiles and exported textiles are derived and estimated. Input demand equations for labor employed in the textile industry and imported cotton were also derived and estimated. In deriving the supply and demand equations, a normalized biquadratic profit function was used. The convexity conditions implied by economic theory were imposed using a technique proposed by Morey.

The coefficients of the restricted profit function were used to calculate the relevant elasticities, including the import demand elasticities for cotton. A single import demand equation for cotton was also estimated and the elasticity was compared to the elasticity derived from a production theory approach. The import demand elasticity based on the single equation specification was 30 percent lower than the estimated elasticity derived from the production theory model.

An important implication of these results is that the nature of the traded good should be taken into account in choosing an appropriate specification. In agriculture, most traded agricultural goods are intermediate in nature. Derived demand equations and elasticities should be based on a fully specified profit maximization (cost minimization) model whenever the data is available to pursue such a strategy.

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